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Individual Differences in Multimedia Learning: An Application in a Computer Science Domain

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***Abstract*— This study looked at the effects that individual differences in prior knowledge have on student understanding in learning with multimedia in a computer science subject. Students were identified as either low or high prior knowledge from a series of questions asked in a survey conducted at the Faculty of Computer and Mathematical Sciences at University Technology MARA, Malaysia. The subject domain chosen for this study is a topic taught to undergraduates in the field of Computer Sciences, in the subject of Operating Systems, i.e., *Memory Management Concepts*. This study utilizes a multimedia application which is shown to a total of 257 students. Early results from the recall and transfer tests indicate that students' individual differences play a vital role in learning outcome. As expected, the low prior knowledge group scored significantly well in the recall tests as compared to the transfer test, and the high prior knowledge group performed comparatively better in the transfer test. This suggests that educational designers who see to foster learning and understanding should adopt the incorporation of learners' prior knowledge as a design principle.**

***Index Terms*—Learning, Memory management, Multimedia Application, Prior Knowledge**

I. Introduction Methods

Learning with computer generated visualizations has become a topic of major interest in recent years. According to Mayer [8][9], multimedia learning is learning from words and pictures and multimedia instructional message or multimedia instructional presentation (or multimedia instruction) is presentation involving words and pictures that is intended to foster learning. Moreover, display design and multimedia combination contributes significantly to learner performance [3][14].

Prior knowledge is important as the learning ability. However, students may have greater prior knowledge, experience and intensive interest, yet have only average learning ability. Using prior knowledge in instructional method seems to be helpful for student with limited knowledge [12]. One of the most persisting findings in the literature of adult learning is that prior knowledge acts both as a filter and as a cognitive peg; restricting and facilitating the acquisition of new knowledge. What one already knows about a topic and one's perspective regarding that topic influence what is remembered [7]. Prior knowledge has been considered the most important single factor that influences learning. Jonassen and Grabowski[2] defined prior knowledge and achievement as the knowledge, skills or abilities that the learners brings to the learning environment before the instruction. Hannafin[1] suggested that compared to individuals who have lower prior knowledge, and individuals who have higher prior knowledge can quickly determine their needs, generate their own learning strategies, and assimilate new information to their existing knowledge structure. Reiber[15] also stated related prior knowledge provides the learners unique relevant elaboration that is unavailable to learners with limited prior knowledge. It is suggested that knowledge will be encoded more meaningfully and retrieved more easily by learners with high prior knowledge. According to Kalyuga[4] level of learners' prior knowledge or experience could affect the effectiveness of an instructional technique. It could be predicted that students understanding of a topic in multimedia application could depend on levels of learners' prior knowledge, thus, the motivation for this study.

To investigate further, this study will look at the effects of low prior knowledge students and high prior knowledge students on both recall and transfer test for a subject taught to undergraduates in the field of information technology and computer sciences.

The subject taught in this multimedia presentation is a topic from operating systems, memory management. Operating Systems (OS) is an important course in many Computer Science, Information Science and Computer Engineering curricula. Some of its topics require a careful and detailed explanation from the lecturer as they often involve theoretical concepts and somewhat complex calculations, demanding a certain degree of abstraction from the students if they are to gain full understanding [13][5].

II. Literature Review

A. The Effects of Prior Knowledge

Prior knowledge has a marked effect on learning outcomes [17] .Mayer and Anderson [6] found that learning significantly improved for students who possess low prior knowledge when verbal and visual information are presented simultaneously. They suggested that experienced students might be able to build referential connections between verbal and visual information and their existing knowledge on their own. A theoretical rationale argued by Mayer [8], is that high-knowledge learners are able to use their prior knowledge to compensate for lack of guidance in the presentation such as by forming appropriate mental images from words - whereas

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low-knowledge learners are less able to engage in useful cognitive processing when the presentation lacks guidance.

In a study looking into prior knowledge as a subject variable that changes outcomes of learning, Shapiro [17] strongly suggest a relationship between prior knowledge and learning outcome. McNamara, Kintsch, Songer and Kintsch [10], used high-school biology content, additional explanatory text was found to benefit only low prior knowledge students. High prior knowledge learners benefited more from minimally coherent instructional materials. McNamara[10] suggested that this effect could be function of more active processing required of the high prior knowledge learner.

B. Assessment of Multimedia Learning

In terms of learning and deeper understanding, a comprehensive assessment is needed. Previous research focused on transfer and retention (recall) learning [8][9].Noting that retention is an important aspect of learning, where the learner is able to remember what was presented in the multimedia treatment, Mayer's Cognitive Theory of Multimedia Learning (CTML) contended that deeper learning occurs when students can transfer the concepts and process to novel situation, and can demonstrate understanding by inference and induction.

III. Methods

A. Participant

Total of 257 students participated in this study. All students were from the Faculty of Computer and Mathematical Sciences at UiTM, Malaysia (173 females and 84 males). There is an uneven number in terms of gender due to the current situation at Malaysian universities where the female population far exceeds the male population.

B. Materials and procedure

This multimedia system was developed using Macromedia Flash MX 2004™. The instructional design is self-paced and content was closely aligned with the textbook [18] used by instructors teaching this subject. All the participants had to take a prior knowledge survey before sitting for the treatment. The prior knowledge survey was conducted in a classroom setting in two different sessions of 20 minutes. This is to determine if the students had high or low prior knowledge. A similar methodology was used by Moreno [11] to conduct a research on cognitive load and student understanding. Some of the questions in the survey asked if students had taken the subject of OS prior to this survey. (Some first year students have already taken an introductory course in OS in their Diploma). Also some basic questions on memory management were asked and students were supposed to tick in the available boxes if they were familiar with certain terms. A total of 120 students from that pool of students were identified as low prior knowledge and 137 students were of high prior knowledge category. An initial investigation indicated that students who were categorized in the high prior knowledge category were undergraduate students who had completed their diploma in computer science and were continuing their degree with some transfer credits; whereas, the low prior knowledge students were foundation students in their first semester.

C. The Experiment

The experiment was conducted in different time frames. This is because the experiment was conducted during the semester where student's class schedules were full and there were limited amount of labs in the faculty to conduct the experiments at once. The multimedia-based instruction explains on the memory management concepts which consist of background on memory management, swapping technique; contiguous allocation technique and paging technique. Then the students were asked to view the multimedia instructions which were installed in each computer in the computer lab. The animation was self-paced and interactive. Students could view the animation with the play button and they could rewind, pause or stop according to the needs. After the treatment, each participant had to take a test.

D. Post-test

A multiple-choice, paper-based test was given to all participants who viewed the multimedia treatment. This test procedure followed the conventional paradigm used to evaluate the mental model constructed during multimedia learning [7]. All the course materials and test questions were validated by the course matter experts from the Faculty of Computer and Mathematical Sciences, UiTM, Shah Alam. The tests were divided into two parts, which are, the recall test and transfer test. Recall test asked questions which required them to recall or remember some basic facts mentioned in the slides. The transfer test required them to solve some problems based on the knowledge learned in the multimedia system. The recall test had some fill in the blanks and multiple choice questions whereas, the transfer test had only multiple choice questions. The transfer test required the students to really understand the calculation method and formula to solve the problem stated.

IV. Results

A. Effects from Recall and Transfer Scores

The low and high prior knowledge is based on one other principle of Mayer's cognitive theory of multimedia learning on Individual Differences principle. This principle states that design effects are stronger for low-knowledge learners than for high-knowledge learners. Below is the hypothesis and results for this investigation.

Hypotheses $_1$: There is a significant difference for low prior knowledge students and high prior knowledge students on the recall score test (%).

$$(H_0: \mu_{Low} = \mu_{High} \quad vs. \quad H_1: \mu_{Low} \neq \mu_{High})$$

Based on Table 1, the results indicate that there was a significant difference between low prior knowledge and high prior knowledge students on the recall score tests since the *p*-value = 0.000. But in this result, students who had a low prior knowledge on operating systems got a higher mean

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TABLE I. INDEPENDENT SAMPLE T-TEST ON THE RECALL SCORE TEST

Student	Mean	Std. Deviation	N	t-value	p-value
Low prior knowledge	64.3333	18.5497	120	6.248	0.000
High prior knowledge	50.0000	18.1695	137		

score (64.3%) as compared to the students with high prior knowledge (50.0%) on the recall score test.

Hypotheses $_2$: There is a significant difference for low prior knowledge students and high prior knowledge students on the transfer score test (%).

$$(H_0: \mu_{Low} = \mu_{High} \quad vs. \quad H_1: \mu_{Low} \neq \mu_{High})$$

TABLE II. INDEPENDENT SAMPLE T-TEST ON THE TRANSFER SCORE TEST

Students	Mean	Std. Deviation	N	t-value	p-value
Low prior knowledge	34.6429	18.0191	120	-13.134	0.000
High prior knowledge	60.4015	13.3123	137		

Based on the independent sample *t*-test result(Table 2), there was a significant difference between low prior knowledge and high prior knowledge students on the transfer score tests since the p-value less than 0.05. The high prior knowledge students got higher score (60.4%) as compared to the low prior knowledge students (34.6%) on the transfer score. This result corresponds to what was expected of this research. Both the hypotheses were accepted.

B. Effects from Prior Knowledge

Hypotheses $_3$: There is a significant difference on student recall scores and transfer scores for low prior knowledge students.

$$(H_0: \mu_{Recall} = \mu_{Transfer} \quad vs. \quad H_1: \mu_{Recall} \neq \mu_{Transfer})$$

TABLE III. PAIRED SAMPLE T-TEST ON THE SCORE TEST FOR LOW PRIOR KNOWLEDGE STUDENTS

Test	Mean	Std. Deviation	N	t-value	p-value
Recall Knowledge Scores	64.3333	18.5497	120	13.420	0.000
Transfer Knowledge Scores	34.6429	18.0191	120		

A Paired Samples *t*-Test was used to compare the recall and transfer score tests on low and high prior knowledge students. A Paired Sample *t*-test compares the means of two variables. It computes the difference between the two variables for each case, and tests to see if the average difference is significantly different from zero[20].

Based on the paired *t*-test result that can be observed in Table 3, there was a significant difference between recall knowledge scores and transfer knowledge scores for low prior knowledge students since the *p*-value = 0.000. Students, who had low prior knowledge on operating systems, got a higher score on recall knowledge questions (64.3%) as compared to those students who answered the transfer knowledge questions (34.6%).

Hypotheses $_4$: There is a significant difference on student recall scores and transfer scores for high prior knowledge students.

$$(H_0: \mu_{Recall} = \mu_{Transfer} \quad vs. \quad H_1: \mu_{Recall} \neq \mu_{Transfer})$$

TABLE IV. PAIRED SAMPLE T-TEST ON THE SCORE TEST FOR HIGH PRIOR KNOWLEDGE STUDENTS

Test	Mean	Std. Deviation	N	t-value	p-value
Recall Knowledge Scores	74.9635	15.8636	137	13.138	0.000
Transfer Knowledge Scores	50.0000	18.1695	137		

Based on the Paired T-test result in Table 4, there was a significant difference on recall knowledge scores and transfer knowledge scores for high prior knowledge students since the *p*-value = 0.000. Students, who had a high prior knowledge on operating systems, got a higher score on recall knowledge questions (75.0%) as compared to students who attempted the transfer knowledge questions (50.0%). The hypotheses were accepted.

V. DISCUSSION

This was another research question that was explored in the experiments conducted on the learning prototypes. The research investigated whether student's prior knowledge affects the post test outcome. Moreover, all the samples represented students who entered the undergraduate degree program at UiTM were from either Matriculation or Diploma programs. Findings of this research is certainly useful for both the educators and learners to know if high and low prior knowledge of learners have any significant effect in learning using different modes of instructions.

Findings of this study indicated that there was a significant difference for students with low and high prior knowledge on the recall score tests. Result showed that students who had low prior knowledge on operating systems obtained a higher mean score, compared to students with high prior knowledge.

Students with low prior knowledge on operating systems obtained a higher score on recall knowledge questions compared to students with low prior knowledge who answered the transfer knowledge questions. The findings showed that there was a significant difference for recall and transfer knowledge scores for students with low prior knowledge. Students with low prior knowledge on operating systems obtained a higher score on recall knowledge questions compared to students who answered the transfer knowledge questions. According to Schnotz and Bannert [16], graphic facilitates learning only if individuals have low prior knowledge and if the subject matter is visualized in a task-appropriate manner. Good graphic design is beneficial for individuals with low prior knowledge who need pictorial support in constructing mental models. However, it is also beneficial for individuals with high prior knowledge. This is inappropriate because forms of visualization can hinder their mental model construction [16].

Basically, both learners with low and high prior knowledge

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performed better in recall compared to transfer questions. However, after examining the results, students with high prior knowledge performed better in the transfer questions compared to students with low prior knowledge, even though the total scores were not significant. The transfer questions required students to think and apply what they know to solve problems. Some mathematical questions were asked which required them to use some formulae. As expected, students with low prior knowledge did not perform well in the transfer knowledge questions. Serafino [21] found that students with high prior knowledge often performed better with complex problem-solving questions. This is because transfer is described as the ability of students to apply prior knowledge to a setting which is sufficiently novel that new learning is required [19]. Based on this research, the results obtained showed that some interaction had occurred between prior knowledge of students and instructions learned to produce some effective transfer of knowledge.

Conclusions

The research investigated whether student's prior knowledge affects the post test outcome. This experience has developed a better understanding of the relationship between student experience levels and instructional design methods as suggested by Sweller[19] and Riaza & Halimah [14].

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